Disappointing success of electrical cardioversion for new-onset atrial fibrillation in cardiosurgical ICU patients

Arrigo, Mattia ; Jaeger, Natalie ; Seifert, Burkhardt ; Spahn, Donat R ; Bettex, Dominique ; Rudiger, Alain

Abstract: OBJECTIVES: To assess the success of electrical cardioversion for the treatment of new-onset atrial fibrillation in critically ill patients and to evaluate the stability of sinus rhythm in responders during the subsequent 24 hours. DESIGN: Retrospective study. SETTING: Twelve-bed cardiosurgical ICU at a university hospital. PATIENTS: Seventy-two consecutive patients with postoperative new-onset atrial fibrillation (< 7 d of duration) treated by electrical cardioversion. INTERVENTIONS: Electrical cardioversion using synchronized biphasic shocks. MEASUREMENTS AND MAIN RESULTS: During 144 electrical cardioversions, 209 shocks were delivered to 72 patients. Maximal energy (200 J) was used in 85% of shocks. Electrical cardioversion immediately restored sinus rhythm in 102 sessions (71%). Pretreatment with amiodarone did not increase the success rates. During the follow-up, the percentages of sinus rhythm decreased from 43% after 1 hour to 23% after 24 hours. However, at ICU discharge, 54 patients (75%) were in sinus rhythm. Of the 54 patients in sinus rhythm, only 18 (33%) converted to sinus rhythm after repeated cardioversions, whereas the remaining 36 (66%) did so spontaneously or with amiodarone. CONCLUSIONS: Biphasic electrical cardioversion in cardiosurgical ICU patients was immediately successful in restoring sinus rhythm in 71% of sessions. However, early relapse of atrial fibrillation was common in the 24-hour follow-up. At ICU discharge, the majority of patients were in sinus rhythm, but the efficacy of repetitive electrical cardioversion in restoring sinus rhythm was disappointing.

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Disappointing Success of Electrical Cardioversion for New-Onset Atrial Fibrillation in Cardiosurgical ICU Patients*

Mattia Arrigo, MD[1,2]; Natalie Jaeger, MD[1]; Burkhardt Seifert, PhD[3]; Donat R. Spahn, MD, FRCA[1]; Dominique Bettex, MD[1]; Alain Rudiger, MD[1]

***See also p. 2510.**

[1]Cardiosurgical Intensive Care Unit, Institute of Anesthesiology, University Hospital Zurich, Zurich, Switzerland.

[2]Department of Cardiology, University Heart Center, University Hospital Zurich, Zurich, Switzerland.

[3]Epidemiology, Biostatistics and Prevention Institute (EBPI), Department of Biostatistics, University of Zurich, Zurich, Switzerland.

Drs. Arrigo and Jaeger contributed equally as first authors.

Drs. Bettex and Rudiger contributed equally as senior authors.

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For information regarding this article, E-mail: alain.rudiger@usz.ch

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Objectives: To assess the success of electrical cardioversion for the treatment of new-onset atrial fibrillation in critically ill patients and to evaluate the stability of sinus rhythm in responders during the subsequent 24 hours.

Design: Retrospective study.

Setting: Twelve-bed cardiosurgical ICU at a university hospital.

Patients: Seventy-two consecutive patients with postoperative new-onset atrial fibrillation (< 7 d of duration) treated by electrical cardioversion.

Interventions: Electrical cardioversion using synchronized biphasic shocks.

Measurements and Main Results: During 144 electrical cardioversions, 209 shocks were delivered to 72 patients. Maximal energy (200 J) was used in 85% of shocks. Electrical cardioversion immediately restored sinus rhythm in 102 sessions (71%). Pretreatment with amiodarone did not increase the success rates. During the follow-up, the percentages of sinus rhythm decreased from 43% after 1 hour to 23% after 24 hours. However, at ICU discharge, 54 patients (75%) were in sinus rhythm. Of the 54 patients in sinus rhythm, only 18 (33%) converted to sinus rhythm after repeated cardioversions, whereas the remaining 36 (66%) did so spontaneously or with amiodarone.

Conclusions: Biphasic electrical cardioversion in cardiosurgical ICU patients was immediately successful in restoring sinus rhythm in 71% of sessions. However, early relapse of atrial fibrillation was common in the 24-hour follow-up. At ICU discharge, the majority of patients were in sinus rhythm, but the efficacy of repetitive electrical cardioversion in restoring sinus rhythm was disappointing. (*Crit Care Med* 2015; 43:2354–2359)

Key Words: atrial fibrillation; cardiac surgery; critically ill; electrical cardioversion; intensive care unit

Synchronized electrical cardioversion (ECV) of atrial fibrillation (AF) is recommended in patients with hemodynamic instability (1–3). ECV may therefore be favorable for critically ill patients with new-onset AF, although evidence from randomized trials is lacking. Success rates of up to 90% have been documented in outpatients (4), but data about conversion rates in critically ill are scarce. Mayr et al (5) reported an immediate success of 35% in 37 postoperative critically ill patients with new-onset supraventricular tachycardia. However, several strategies have been implemented into clinical practice since. Higher initial delivered energy (6, 7), anterior-posterior electrode positioning (8, 9), biphasic waveforms (10), and pretreatment with antiarrhythmic drugs (11–13) all improve the success of ECV in outpatients, but the efficacy of these measures in critically ill patients is unclear. In this context, a reappraisal of the efficacy of ECV in critically ill patients with new-onset AF is warranted. The aims of our study were 1) to assess the immediate success of ECV in a cardiosurgical ICU population, 2) to document the stability of sinus rhythm after successful ECV during the subsequent 24 hours, and 3) to investigate factors influencing the success.

METHODS

Study Site and Population

This study was performed in the cardiosurgical ICU at the University Hospital Zurich, Switzerland. In the year 2013, 1,181 patients were treated in this 12-bed ICU. Median Simplified Acute Physiology Score (SAPS) and ICU mortality of all admitted patients were 31% and 4.3%, respectively.

Consecutive patients with new-onset AF treated by ECV were included from September 1, 2013, to September 1, 2014. Patients fulfilling the definition of permanent AF or with other forms of supraventricular tachycardia were excluded from the analysis.

Definition of New-Onset AF

AF was defined according to the guidelines of the European Society of Cardiology (2). Episodes of AF were detected by the nurse or physician on the continuous electrocardiogram monitoring and confirmed by a 12-lead electrocardiogram. New-onset AF was defined as AF for less than 7 days.

ECV

ECV was performed with a ZOLL M-series external defibrillator (ZOLL Medical, Chelmsford, MA) and COVIDIEN MediTrace Cadence Multi-Function electrodes (COVIDIEN, Dublin, Ireland). All applied shocks were electrocardiogram triggered (synchronized) and of biphasic waveform. Anteroposterior electrode positioning was applied if possible. Physicians were encouraged to administer a high initial energy with escalating doses for subsequent shocks. Repeated shocks within 15 minutes were defined as an ECV session.

A conversion into sinus rhythm for at least 30 seconds during an ECV session was defined as a successful ECV. The stability of sinus rhythm during the following 24 hours was investigated, and the presence of sinus rhythm at ICU discharge was documented.

Data Collection and Statistical Analysis

Delivered energy, number of shocks, electrode position, and immediate success were documented by the treating physicians. The remaining data were collected by reviewing the patient's charts. Pretreatment (6 hr before the ECV) and posttreatment (after ECV until ICU discharge) with antiarrhythmic drugs were recorded. Hemodynamic instability was defined as noradrenaline requirements greater than or equal to 0.1 μg/kg/min to keep the mean arterial pressure greater than or equal to 65 mm Hg or a need for inotropes or signs of heart failure or evidence of circulatory shock (serum lactate ≥ 2.2 mmol/L or central venous oxygen saturation < 60%). Respiratory failure was defined as a need for mechanical ventilation. Renal failure was defined as serum creatinine greater than or equal to 200 μmol/L or a need for renal replacement therapy.

Values are given as median (range) or number (percentages), as appropriate. Groups (successful vs unsuccessful ECV) were compared using the Mann-Whitney *U* test or the Fisher

TABLE 1. Baseline Characteristics of the Patients at the Onset of Atrial Fibrillation

Variable	*n* = 72
Type of cardiac surgery, *n* (%)	
Coronary artery bypass grafting surgery	23 (32)
Valve surgery	37 (51)
Aortic surgery	26 (36)
Other cardiac surgery	19 (26)
Left ventricular ejection fraction (%)	55 (10–75)
Simplified Acute Physiology Score II (points)	50 (22–106)
Body temperature (°C)	37.0 (33.9–38.6)
Laboratory values at the onset of atrial fibrillation	
Hematocrit (%)	26 (21–41)
Leukocyte (10^3/μL)	13 (4.3–40)
C-reactive protein (mg/L)	128 (1–441)
Potassium (mmol/L)	4.9 (3.4–7.2)
Magnesium (mmol/L)	1.04 (0.71–1.73)
Calcium, ionized (mmol/L)	1.17 (0.99–1.40)
Troponin T (μg/L)	0.72 (0.02–18)
Creatinine (μmol/L)	113 (11–458)
Backup pacing, *n* (%)	
Ventricular only	16 (22)
Atrial and ventricular	18 (25)
None	38 (53)

Values are given as median (range) or number (%). Many patients received combined surgical interventions; therefore, the sum of the procedures exceeds 100%. Twelve patients (17%) received combined coronary artery bypass grafting and valve surgery.

exact test, as appropriate. ECVs were considered stochastically independent as groups were compared. AF relapse over time was described with the Kaplan-Meier curve, and differences between groups were assessed by the log-rank test. The null hypothesis was rejected with a two-sided p value of less than 0.05. All analyses were performed with the use of IBM SPSS Statistics, version 21.0 (IBM, Armonk, NY).

Ethical Considerations

The study protocol was approved by the local ethical committee (KEK-ZH no. 2014-0389). Due to the nature of the study, patient's informed consent was waived by the ethical committee.

RESULTS

Population

A total of 72 patients were included (72% men; age, 72 yr [36–94 yr]; body mass index, 27 kg/m^2 [16–41 kg/m^2]). AF developed on postoperative day 3 (1–29). **Table 1** summarizes the baseline characteristics of the patients. All patients received appropriate anesthesia before ECV.

Immediate Success of Electrical Conversion

Thirty-seven patients (51%) had one ECV; the remaining had up to six ECVs during their ICU stay. Finally, a total of 144 ECVs were analyzed in the study. During those ECVs, 209 shocks were delivered with a median of 1 (1–5) shock per ECV. **Figure 1*A*** illustrates the success of ECV after the first, second, and third shocks. Finally, the restoration of sinus rhythm was achieved in 102 ECVs (71%).

Seventy-five ECVs (52%) were performed with electrodes in the anteroposterior position; the remaining required anterolateral electrode placements. Eighty-five percent of shocks were performed with a maximal biphasic energy of 200 J (**Fig. 1*B***). ECVs were performed after 2.75 hours (0–144 hr) from AF onset. A comparison between successful ECV and unsuccessful ECV is displayed in **Table 2**. Immediate ECV success in patients with (n = 56) and without (n = 88) aortic surgery was 44 (79%) and 58 (66%), respectively (p = 0.13). Hemodynamic instability was present during 117 ECVs (81%) and had no influence on the ECV success (71% vs 70%; p = 1.0). One hundred five ECVs (73%) were performed in patients with respiratory failure (invasive ventilation, n = 102; noninvasive ventilation, n = 3). IV amiodarone was administered during the 6 hours before ECV in 94 of 144 cases (150 mg, n = 41; ≥ 300 mg, n = 54). Amiodarone pretreatment was present in 68 successful ECVs (67%) and 26 unsuccessful ECVs (62%), and therefore, it did not significantly affect the immediate success of ECV (p = 0.36). IV esmolol was administered before 10 ECVs. No differences in the immediate success was observed (p = 1.0). Pretreatment with oral antiarrhythmic drugs was not performed in any patient.

Stability of Sinus Rhythm

Figure 2 shows the Kaplan-Meier curve documenting the percentage of patients in sinus rhythm during the 24 hours following ECV. **Table 3** summarizes the success rates of ECV at different time points. Pretreatment with amiodarone showed no significant influence on the maintenance of sinus rhythm during the first 24 hours (log-rank test p = 0.61).

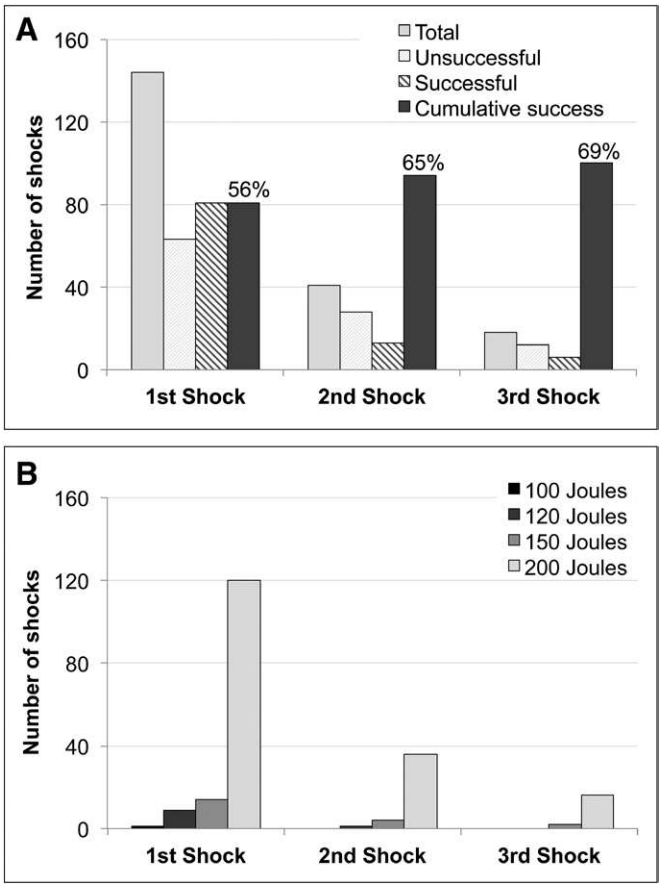

Figure 1. A, Success of electrical cardioversion. The first bars illustrate the total numbers of shocks. Shocks not converting atrial fibrillation to sinus rhythm are shown as unsuccessful (*light gray bars*), and those achieving conversion to sinus rhythm are classified as successful (*hatched bars*). *Black bars* illustrate the total number of conversions to sinus rhythm after the first, second, and third shock. The success rates were 56%, 65%, and 69% after the first, second, and third shock, respectively. After four or more shocks, the cumulative success rate of electrical cardioversion was 71%. **B**, Delivered energy. The figure illustrates the delivered energies during the first, second, and third shock. The first shock was successful in 62% if the initial energy was 200 J. With lower energies, the success rate of the first shock decreased (36% for 150 J, 22% of 120 J, and 0% for 100 J).

Outcome

The median length of ICU stay was 7 days (1–31 d), and ICU mortality of the study population was 15%. At ICU discharge, 54 patients (75%) were in sinus rhythm, whereas 18 patients (25%) were still in AF. Of the 54 patients in sinus rhythm, 11 (20%) converted spontaneously, 25 (46%) after amiodarone posttreatment, and 18 (33%) after repeated ECV.

DISCUSSION

We performed a retrospective analysis of 209 shocks delivered during 144 ECV to 72 patients with postoperative new-onset AF hospitalized in a cardiosurgical ICU. There were three main

TABLE 2. Characteristics of Successful and Unsuccessful Electrical Cardioversion

Variable	Total ($n = 144$)	Successful ECV ($n = 102$)	Unsuccessful ECV ($n = 42$)	p
Demographics				
Age (yr)	71 (36–94)	72 (36–91)	70 (47–94)	0.47
Male gender, *n* (%)	106 (74)	76 (75)	30 (71)	0.68
Weight (kg)	75 (46–126)	75 (46–126)	76 (53–126)	0.77
Body mass index (kg/m^2)	27 (16–41)	27 (16–41)	28 (18–41)	0.17
Left ventricular function				
Left ventricular ejection fraction (%)	55 (10–75)	55 (10–73)	55 (20–75)	0.88
Type of cardiac surgery, *n* (%)				
Coronary artery bypass grafting surgery	46 (32)	29 (28)	17 (41)	0.17
Valve surgery	76 (53)	51 (50)	25 (60)	0.36
Aortic surgery	56 (39)	44 (43)	12 (29)	0.13
Simplified Acute Physiology Score II (points)	50 (22–106)	50 (22–106)	47 (24–82)	0.60
Body temperature (°C)	37.2 (33.9–38.8)	37.2 (33.9–38.5)	37.2 (34.7–38.8)	0.91
Hemodynamic status				
Mean arterial pressure (mm Hg)	70 (40–90)	70 (40–90)	63 (40–80)	0.19
Heart rate (beats/min)	110 (60–200)	110 (60–200)	105 (70–185)	0.17
Norepinephrine (μg/kg/min)	0.11 (0.00–0.66)	0.10 (0.00–0.66)	0.14 (0.00–0.59)	0.27
Inotropes	77 (55%)	53 (54%)	24 (60%)	0.57
Adrenaline	59 (41%)	39 (38%)	20 (48%)	0.35
Dobutamine	2 (1%)	2 (2%)	0 (0%)	1.0
Milrinone	42 (29%)	25 (25%)	17 (41%)	0.07
$Svo_2/Scvo_2$ (%)	66 (38–89)	66 (38–89)	67 (50–78)	0.51
Lactate (mmol/L)	1.2 (0.1–12)	1.2 (0.1–12)	1.3 (0.6–8)	0.23
Organ dysfunction, *n* (%)				
Respiratory failure	105 (73)	74 (73)	31 (74)	1.0
Renal failure	50 (35)	37 (36)	13 (31)	0.57
Laboratory values				
Hematocrit (%)	26 (20–41)	26 (20–41)	26 (20–39)	0.47
Leukocyte (10^3/μL)	15 (4.3–40)	15 (4.3–40)	16 (5.6–37)	0.21
C-reactive protein (mg/L)	129 (1–441)	128 (1–422)	138 (1–441)	0.81
Potassium (mmol/L)	4.9 (3.4–7.2)	4.9 (3.4–7.2)	4.8 (4.1–5.8)	0.31
Magnesium (mmol/L)	1.06 (0.71–1.73)	1.05 (0.71–1.73)	1.06 (0.82–1.71)	0.16
Calcium, ionized (mmol/L)	1.16 (0.99–1.44)	1.15 (0.99–1.44)	1.17 (1.02–1.40)	0.43
Troponin T (μg/L)	0.70 (0.02–18)	0.67 (0.02–18)	0.82 (0.06–7.6)	0.38
Pretreatment with amiodarone	94 (65%)	68 (67%)	26 (62%)	0.70

ECV = electrical cardioversion.

Values are given as median (range) or number (%). p value calculated by Mann-Whitney *U* test or Fisher exact test, as appropriate. $Svo_2/Scvo_2$ = mixed/central venous oxygen saturation (available for 120 ECVs).

findings: first, the immediate success rate of ECV was 71%; second, the stability of sinus rhythm during the subsequent 24 hours was poor (43% at 1 hr; 23% at 24 hr); third, no factor could be identified that differed significantly between successful ECV and unsuccessful ECV. However, repeated electrical and/or pharmacologic interventions as well as spontaneous

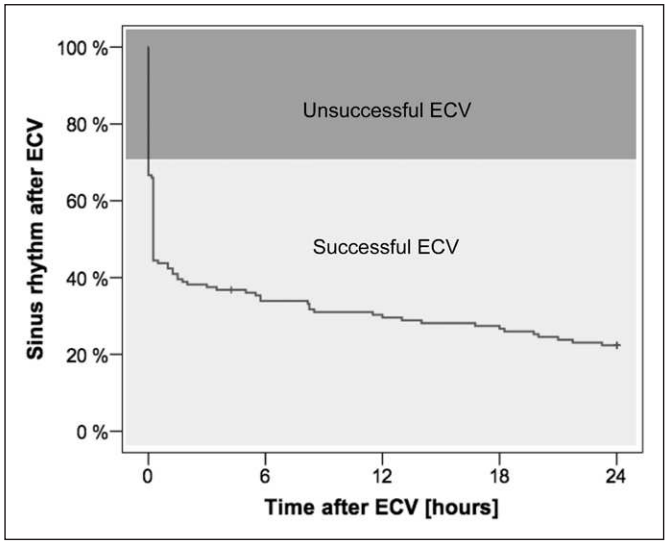

Figure 2. Percentage of sinus rhythm after electrical cardioversion (ECV). The figure illustrates the overall frequency of sinus rhythm after ECV. Atrial fibrillation persisted after 29% of sessions (unsuccessful ECV), whereas ECV was initially successful in restoring sinus rhythm in 71% of sessions.

TABLE 3. Percentage of Patients in Sinus Rhythm After Electrical Cardioversion

Time	Sinus Rhythm (%)
Immediately after ECV	71
15 min after ECV	51
1 hr after ECV	43
6 hr after ECV	34
12 hr after ECV	30
24 hr after ECV	23
ICU discharge	75

ECV = electrical cardioversion.

conversions led to the fact that 75% of patients with de novo AF left the ICU with sinus rhythm.

The immediate success rate of 71% was achieved after one or more shocks. After the first shock, a decreasing success-to-failure ratio was observed during subsequent shocks. Hence, the potential small benefit of additional shocks has to be weighed against the risk of physical myocardial injury. In clinical practice, the authors suggest maximal two shocks of 200 J per ECV and, if necessary, a pause of 2–6 hours before the next ECV attempt. The pathophysiologic peculiarities of critically ill patients following cardiac surgery, such as inflammation, fluid and electrolyte disturbance, adrenergic overstimulation, or surgical trauma, are likely to play a central role in the reduced success rate of ECV compared with the cardiology outpatient setting (14–16).

The success rates of ECV in this study are better compared with the percentages described by Mayr et al (5). They analyzed the success of ECV in treating new-onset AF in 37 postoperative critically ill patients. Success, defined as conversion and persistence of sinus rhythm for at least 5 minutes, was reported in 35% of patients. In contrast to the study by Mayr et al (5), several recommendations for performing ECV (6–10) were implemented in our clinical practice: all delivered shocks were of biphasic waveform, 85% used maximal energy (200 J), and 52% of sessions were performed with anteroposterior electrode position. The different definition of immediate success (30 s in our study compared with 5 min in the work of Mayr et al [5]) may also partially explain this discrepancy. We chose a short time span of 30 seconds to assess the technical success of ECV and avoid confusion with early relapses.

We analyzed several factors potentially influencing the success of ECV, but none of them showed a statistically significant difference between the groups. Even the use of a pretreatment strategy with amiodarone did not influence the immediate success of ECV. We also tried to find predictors of success in multivariable logistic regression, but we did not get any clear association (data not shown).

The analysis of the stability of sinus rhythm after successful ECV addressed the clinical relevant aspect of ECV. During the 24-hour follow-up, AF relapse frequently occurred: 1 and 24 hours after ECV, sinus rhythm was present in only 43% and 23% of patients, respectively. These results are of concern. The benefit of increased immediate success is lost during the first hours because of high relapse rates. A percentage of sinus rhythm of 23% after 24 hours is even lower than the rate of 31% reported by Mayr et al (5). In light of our data, a treatment strategy by ECV alone is likely to be ineffective. Therefore, novel strategies for improving the stability of sinus rhythm after ECV are urgently needed. Sticherling et al (17) showed a decrease in immediate recurrences of AF in patients undergoing elective ECV by administrating amiodarone. However, amiodarone pretreatment was not associated with a higher ECV success in our study.

Spontaneous conversion occurred in 20% of our patients with sinus rhythm at ICU discharge. This result is consistent with rates of spontaneous conversion in patients admitted for new-onset AF (18). In our ICU, amiodarone posttreatment is not common practice in patients responding to ECV. Hence, posttreatment was only investigated in patients with AF relapse and sinus rhythm on discharge. Amiodarone posttreatment led to higher percentage of sinus rhythm at ICU discharge than repeated ECV (46% vs 33%).

Finally, the SAPS II and the mortality of 15% in the study population were higher compared with the yearly averages of all patients hospitalized in this particular ICU. We can therefore postulate that new-onset AF is associated with increased morbidity and mortality and is likely to be a marker of illness severity.

Limitations of the Study

First, the study was limited to 144 ECVs from 72 patients. Nevertheless, this is the largest cohort of surgical ICU patients undergoing ECV for AF reported in the literature. The discrepancy between the low number of included patients and the high prevalence of AF reported after cardiac surgery may be

explained by the following factors: first, patients with history of permanent AF were excluded from the study; second, only AF patients treated with ECV were analyzed, and therefore, patients successfully treated with antiarrhythmic drugs or with spontaneous conversion were not included in the study; third, some patients may have developed postoperative AF after ICU discharge. In our opinion, the key messages of our study do not substantially depend on the size of the studied population. Our data suggest that a larger population might well result in statistically significant differences between the risk factors but that these differences would most likely be clinically irrelevant.

The studied population is a selected cohort of ICU patients because all included patients underwent cardiac and/or major vascular surgery. Hence, the results may not be generalized to all adult ICU patients.

Detection of episodes or relapses of AF was assessed by real-time reading of the continuous electrocardiogram monitoring. This method reflects usual clinical practice but may miss short, subclinical episodes of AF.

The use of anticoagulation for AF was not assessed because the majority of included patients (81%) were considered hemodynamically unstable, and therefore, the decision to perform ECV was not influenced by the coagulation state. In addition, the use of anticoagulation in the early postoperative period was determined mainly by the surgical bleeding risk.

CONCLUSIONS

The management of new-onset AF in critically ill patients is challenging and commonly includes ECV. In this retrospective study including 144 ECVs in 72 patients, immediate success rate of ECV was 71% and therefore higher than previously reported in critically ill patients. However, early relapse of AF was common, so that only 23% of the patients were still in sinus rhythm after 24 hours. Pretreatment with amiodarone did not increase the success. At ICU discharge, 75% of patients were in sinus rhythm, whereby 20% converted spontaneously, 46% after amiodarone posttreatment, and only 33% after repeated ECV. Hence, the efficacy of repetitive ECV in restoring sinus rhythm was disappointing.

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